US ADMINISTRATION

Comparison of Radiated Emission Spectra of Maritime Radiolocation Radars with Rotating Versus Non-Rotating Transmitter Antennas During Measurements in the Bands 2 900-3 100 MHz and 8 500-10 500 MHz

Contact: Frank Sanders, +1-303-497-7600, fsanders@its.blddrdoc.gov
Robert Sole, +1-202-482-1245, rsole@ntia.doc.gov

Introduction.

Emission spectra of radiolocation radars may be measured via direct radiation from the transmitter antenna. The direct technique allows frequency-dependent (and possibly important) effects of the radiating antenna to be automatically included in the final set of emission spectrum data.

The radiated mode of measurement ordinarily implies that the radar antenna will rotate while the measurement is performed. In this case, a single spectrum frequency point needs to be acquired for each revolution of the radar antenna, as described in ITU-R New Recommendation M.1177. This means that the time required to acquire the spectrum is equal to the rotation time of the antenna multiplied by the total number of data points. If, for example, the total number of data points were 1000 and the rotation interval of the radar were 3 seconds, then the total time required for the measurement would be 3000 seconds, or 50 minutes. And in the case of emission measurements of 9000 MHz maritime radars, in which a data point may need to be acquired with a spacing of 1 MHz and in which the measurement might need to cover a frequency range of 7-26 GHz (a total span of 19 GHz), the total measurement time required with a rotation interval of 3 seconds would be 15.8 hours.

The measurement pace could be considerably accelerated if the radar antenna could be suspended during data acquisition. Then, the spectrum data could be acquired at a rate determined by the maximum speed of the measurement system's frequency-stepping capability. If, for example, the data points could be collected at the rate of one point every 0.5 sec, the total time required for the 19 GHz span described above would be 1/6 of 15.8 hours, or 2.6 hours.

In principle, it might be expected that the characteristics of a radar emission spectrum should not depend upon whether the radar antenna is rotating or stationary, but this hypothesis has needed to be tested. This document describes the results of a study that compared the emissions of 3 GHz and 9 GHz maritime radars when their antennas were rotated versus not rotated during radiated spectrum measurements.

Experimental Setup.

Radiated emission spectrum measurements were performed at an outdoor radio measurement facility, in the Table Mountain radio quiet zone north of Boulder, Colorado in the US on two maritime radars, one with a fundamental operating frequency in the 2 900-3 100 MHz band ("S-Band Radar 1") and the other with a fundamental operating frequency in the 8 500-10 500 MHz band ("X-Band Radar 1"). The radars were provided by the Administration of Japan and the measurements were performed jointly by the Administrations of Japan and the US in accordance with the methodology described for the Direct (radiated) Method in M.1177. The measurement system block diagram is shown in Figure 1.

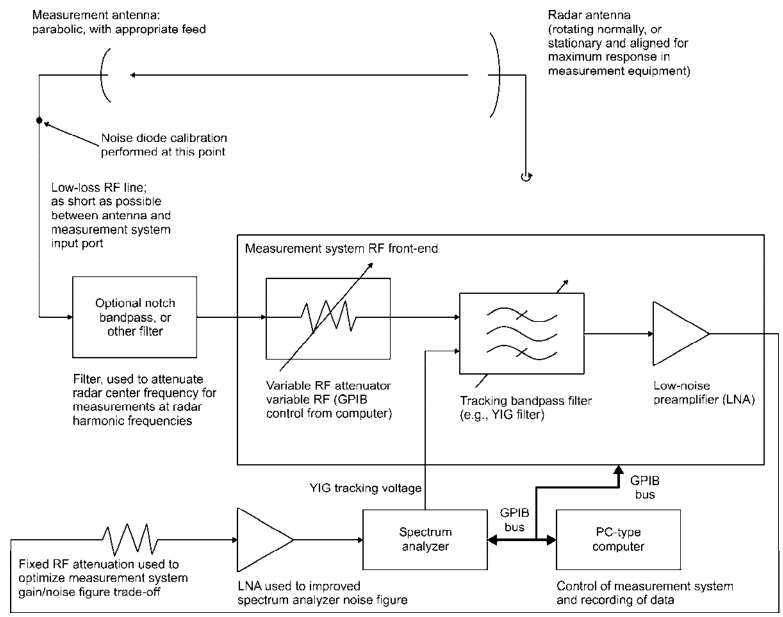

Figure 1. Block diagram of measurement system used for radar emission spectrum measurements.

The measurement antenna was a 1-m parabolic dish located at a height of [4 m] above the ground. The radar antennas were mounted approximately [3 m] above the ground. The distances between the measurement antenna and the radars, the spectrum analyzer models that were used, and the measurement bandwidths are shown in Table 1. Radar characteristics are shown in Table 2. All measurement parameters except rotation versus non-rotation were held constant during measurements for each radar model.

Table 1. Measurement distances, spectrum analyzer models, and measurement bandwidths used for emission spectrum measurements.

Radar	Distance between radar and measurement antenna (m)	Spectrum analyzer model	Measurement bandwidth (MHz)
S-Band Radar 1	366	HP-8566B	3
X-Band Radar 1	83	Agilent E4440A	8

Table 2. Emission characteristics of radars in this study.

Radar Designator	Pulse width (μs)	Output device	Antenna type	Antenna length (m)
S Band Radar 1	0.06	magnetron	end fed slotted array	4.3
X Band Radar 1	0.07	magnetron	end fed slotted array	1.4

Measurement Results.

The emission spectrum measurement results for the conditions of rotation versus non-rotation are shown in Figures 2-3.

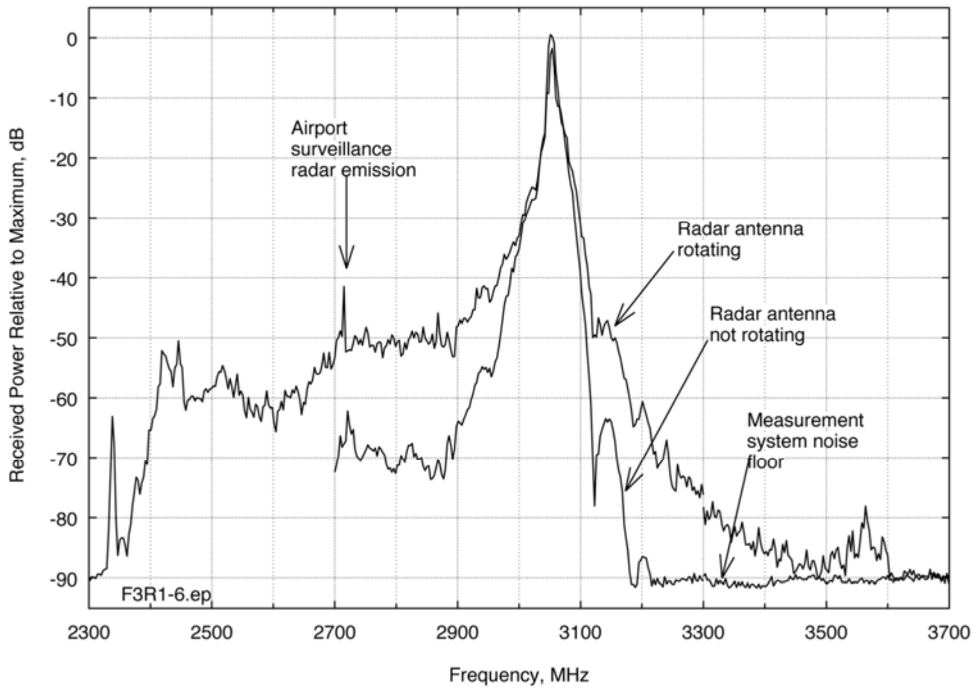

Figure 2. Emission spectra of S-Band Radar 1 with transmitter antenna rotating versus not rotating. Note waveguide cutoff features between about 2 300-2 400 MHz. Airport surveillance radar emission at 2 720 MHz was reduced as much as possible by timing measurement steps to be anti-coincident with the airport radar beam scanning.

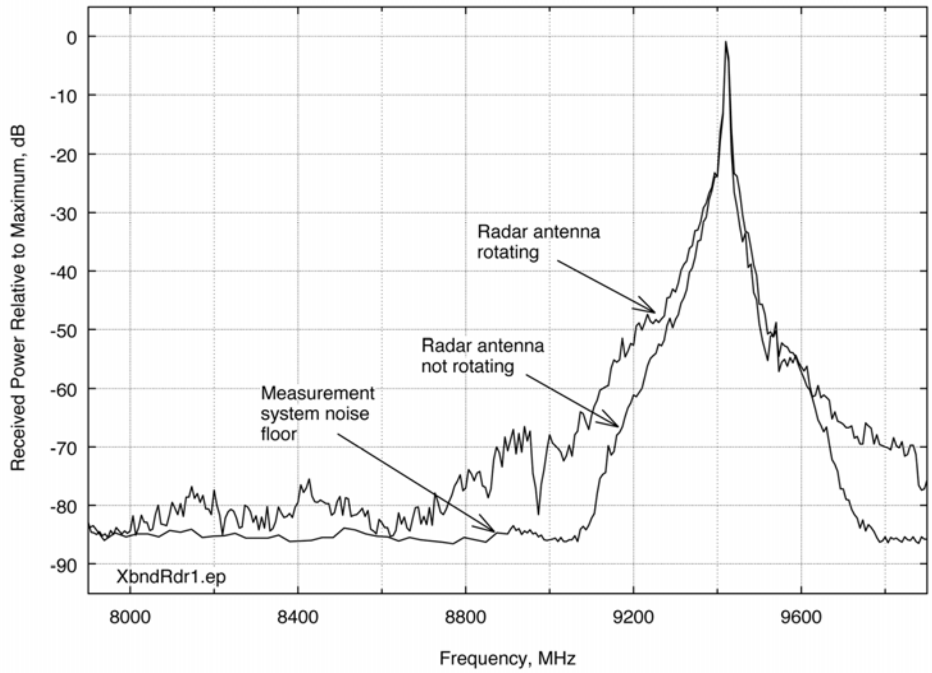

Figure 3. Emission spectra of X-Band Radar 1 with transmitter antenna rotating versus not rotating.

In both cases, the measured emission spectra showed nearly the same amplitudes at the fundamental frequencies regardless of whether the radar transmitter antennas were rotating or stationary. But the emission spectra of unwanted emissions (that is, the out-of-band and spurious emissions) were markedly lower when the transmitter antennas were stationary versus when the transmitter antennas were rotated during the measurements.

To understand this problem more thoroughly, measurements of X Band Radar antenna patterns were performed at intervals of 8 MHz throughout the emission spectrum. For each antenna pattern, the measurement was triggered by the passage of the radar main beam at the fundamental frequency. These measurements showed that, at most frequencies other than the fundamental, the radar antenna pattern formed two lobes rather than one, and that the null between the two lobes occurred where the main beam was formed at the fundamental frequency. An example is shown in Figure 4.

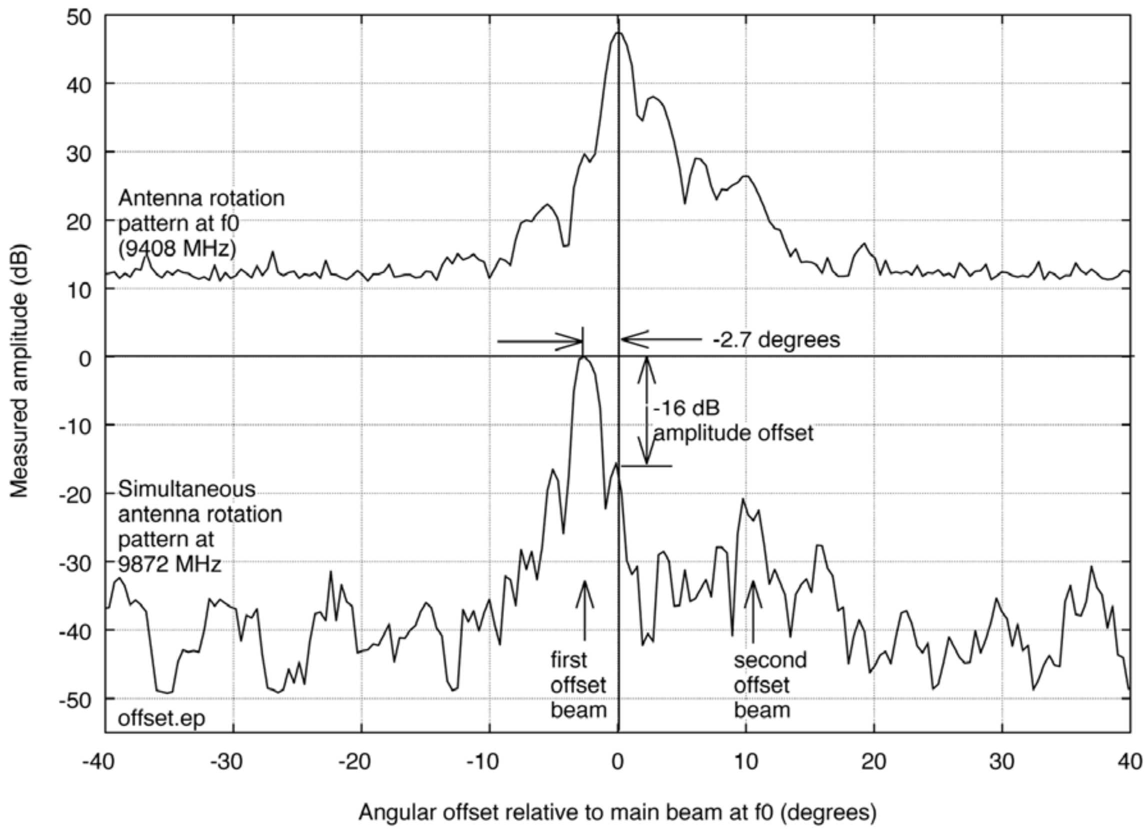

Figure 4. Radar antenna patterns for a slotted array at the fundamental frequency (upper curve) and a simultaneously acquired antenna pattern 464 MHz higher in frequency (lower curve), which was triggered by the passage of the main beam. The frequency-offset antenna pattern forms two lobes, the higher-amplitude lobe in this case being offset 2.7 degrees and 16 dB in amplitude from the position of the main beam at the fundamental. This behavior is observed throughout the spectrum.

Analysis and Interpretation.

Since both radars provided the same emission power on the respective center frequencies, the possibility that the rotary joint of the radar did not perform as well when it was stationary as when it was rotating can be eliminated. Instead, the effect that is observed is clearly frequency-dependent. That is, Figures 2-3 show that the difference between the rotating antenna versus non-rotating antenna measurements grows progressively larger as measured frequencies diverge further from the radar fundamental frequencies.

Figure 4, which shows an example of a behavior that is observed throughout the spectrum, demonstrates the cause of the phenomenon. The slotted array forms a double beam at frequencies other than the fundamental, and the null between the two beams occurs at (or near) the location where the main beam is formed at the fundamental.

As a result of this behavior, spectrum measurements performed on non-rotating radar antennas will result in lower (and incorrect) amplitudes relative to the fundamental power than measurements performed on rotating antennas.

The cause of this phenomenon is the slotted design of the radar antennas, which produces frequency-dependent lobe structures in the antenna patterns.

Conclusion.

For Direct Method radiated emission spectrum measurements, it is desirable to ensure that the radar transmitter antenna is rotated during the measurements if the antenna characteristics cause a frequency-dependent variation in the direction of the main radiation lobes relative to the direction of the main beam at the radar fundamental frequency.

For types of radar transmitter antennas that do not have this characteristic spectrum measurements can be performed with the transmitter antennas held stationary.